ORIGINAL ARTICLE

The relationship between the ratio of interpedicular distance increase and the ratio of spinal canal compromise in thoracolumbar burst fractures

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ABSTRACT

BACKGROUND: The aim of the study was to investigate the relationship between the interpedicular distance increase ratio and the ratio of canal compromise in thoracolumbar burst fractures.

METHODS: Thirty-one patients (18 male and 13 female) with an average age of 30.8 (14–57) who had been treated for thoracolumbar burst fractures in the Department of Orthopaedics and Traumatology were included in the study. The initial anteroposterior radiographs of the patients were used to calculate the increase ratio of interpedicular distance (both from medial-to-medial and from center-to-center). The area measurements from the computerized tomography or magnetic resonans images were used to calculate the canal compromise. The relationship between the increase ratio of interpedicular distance and the ratio of canal compromise was investigated by correlation and linear regression analysis.

RESULTS: There was a "very good" correlation between the from medial-to-medial and from center-to-center measurements of interpedicular distance (Pearson correlation coefficient: 0.89, $p<0.001$). The correlation between the ratio of canal compromise and from medial-to-medial and from center-to-center measurements of interpedicular distance was "good" with Pearson correlation coefficients of 0.60 and 0.63, respectively ($p<0.001$). No statistically significant relationships were found between the fracture levels, types, neurologic status of the patients, and the increase ratio of interpedicular distance or the ratio of canal compromise.

CONCLUSION: Depending on the correlation coefficients which were obtained in this study: To predict the canal compromise from the ratio of interpedicular distance increase is not a reliable method for all of the patients.

Keywords: Interpedicular distance; spinal canal compromise; thoracolumbar burst fracture.

INTRODUCTION

Burst fractures of the thoracolumbar spine account for 25–50% of all spine injuries. These fractures are often associated with kyphotic deformity and significantly affect patients' daily physical activities.[1,2] In burst fractures, retropulsion of the fracture fragments into the spinal canal from the corpus posterior, that is, from the middle column, may be the cause of neurological deficit due to the compression of the spinal cord within the canal.[3,4] The ratio of canal compromise of these bone fragments is one of the critical parameters in determining the indication for the treatment of burst fractures.[5,6] Radiological methods that best illustrate the invasion of the canal are computed tomography (CT) and magnetic resonance imaging (MRI), which allow for cross-sectional imaging, with which in particular transverse sections can be obtained.

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[7] One of the most critical features of burst fractures in direct anteroposterior (AP) radiographs is the increase in interpedicular distance.[3]

In this study, we aimed to investigate the relationship between the ratio of interpedicular distance increase calculated based on the interpedicular distance measurements on direct radiographs and the ratio of spinal canal compromise, which can only be detected by cross-sectional imaging.

MATERIALS AND METHODS

This study was initiated after receiving the approval of İstanbul University Cerrahpaşa Faculty of Medicine Ethics Committee on December 6, 2005, numbered 33993. The files of 106 patients with thoracolumbar spine burst fractures who were hospitalized in the Orthopedics and Traumatology Department and whose archive records were available were examined. Thirty-one patients who were <60 years of age and had a T10-L3 thoracolumbar spine burst fracture, a single-level fracture, had no history of spine fractures or surgery, no known neoplastic disease, no congenital spinal anomalies or deformities, no metabolic bone disease, and those who had lack of rotation on AP radiographs that affect the interpedicular distance measurement were included in the study.

Of the 31 patients included in this study, 18 (58.1%) were males and 13 (41.9%) were females, with a mean age of 30.8 years (range: 14–57 years, SD: 12.6). The fracture mechanism was fall from a height in 18 patients, in-vehicle traffic accident in seven patients, out-vehicle traffic accident in two patients, falling down the stairs in two patients, beating in one patient, and staying underweight in one patient.

The fractures were at the level of T12 in 4 patients (12.9%) (Fig. 1), L1 in 15 patients (48.4%), L2 in 8 patients (25.8%), and L3 in 4 patients (12.9%). According to the Denis classification, 24 patients (77.4%) had Type B burst fractures and the remaining 7 (22.6%) had Type A burst fractures. Fourteen patients had concomitant orthopedic injuries. Since the neurological status of all patients was not available according to a classification system (such as Frankel or ASIA), they were evaluated as "normal," "partial damage," and "paraplegia". Accordingly, two patients had paraplegia, six patients had partial damage, while 23 patients were found to be normal.

CT or MRI films including direct AP and lateral radiographs and fracture-level transverse sections of the patients were scanned using a professional scanner (Linotype-Hell Chromagraph S3400 drum scanner, Heidelberg) at 200 pixel/inch (78.74 pixel/cm) resolution and saved in "TIF" format. In addition, a film was shot by placing a metal-sized wooden ruler 5 cm anterior of the T10-L3 vertebra pedicles, approximately the distance of the pedicles from the tube when the AP radiograph was taken, and this film was scanned using the same scanner. Lateral radiographs were used only in determining the fracture level and type.

The scanned AP images were opened using the Adobe Photoshop v.8.0 (Adobe Inc., San Jose, CA, USA) program. The interpedicular distance measurements (medial-to-medial and middle-to-middle) of the fracture level and the upper and lower intact levels were recorded using the measure tool in this program. To standardize the measurements shown in centimeters, the length of 10 cm on the scanned image of the metal scale ruler radiography was measured by the same method. The coefficient calculated in this way was multiplied by the other length measurement results to normalize all lengths. To calculate the ratio of interpedicular distance increase at the fracture level, natural interpedicular distance values of this level are required. This value was calculated by averaging the values of the upper and lower intact levels. The expected interpedicular distance value calculated by this method was subtracted from the measured value for each patient. The result was then divided by the expected interpedicular distance value, and the value obtained was multiplied by 100 to find the interpedicular distance increase rate as a percentage (%) (Fig. 2).

For the normal and compromised canal area measurements, the transverse CT or MRI sections of the fracture level were examined, and the most compromised section was deter-

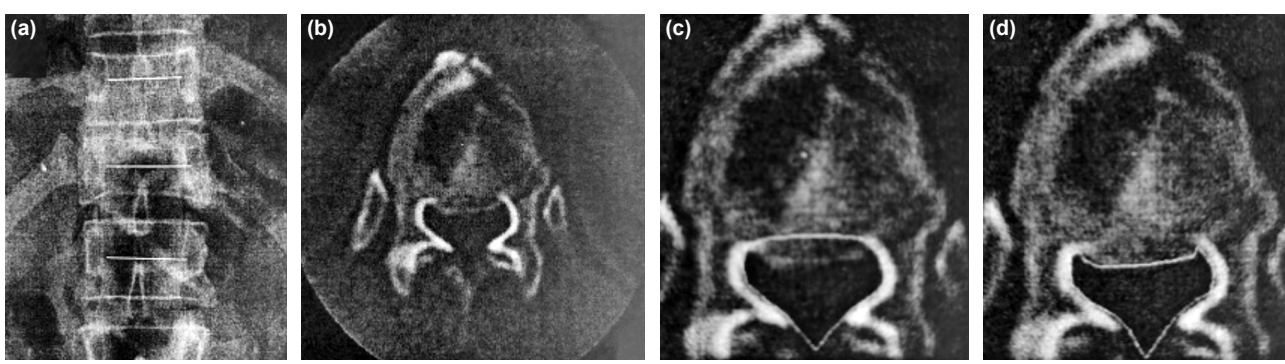

Figure 1. Fifty-year-old man, T12 burst fracture. **(a)** In AP radiography, increase in interpedicular distance in T12 is seen compared to the upper and lower levels, **(b)** CT section where intracanal compromise is maximum, **(c)** image of normal canal boundaries drawn by extrapolation in the autocad program in the CT section, and **(d)** compromised canal boundaries drawn in autocad program in the same section.

mined. The digital image of this section was opened in the AutoCAD® 2000 (Autodesk Inc., San Rafael, CA, USA) software. The normal canal area of the fracture level was extrapolated with the polyline tool of this program, and the occupied canal area was drawn over the bone boundaries. Fields of these drawings were determined by finding the value against the field section and were then saved. The compromised canal area detected for each patient was divided by the detected normal canal area and calculated as a percentage (%).

The distance of 1 cm shown on the scale in the CT or MRI section frame was drawn using the "Line" tool of the AutoCAD® 2000 program. The length of the drawn line was determined and was then saved. In this way, the real value of 1 cm was determined by the digital value (pixel) on the digital image. The square of this value was found and the digital field value corresponding to the 1 cm^2 area was calculated. With the help of this value calculated separately for each patient's section, the "normal" and "compromised" canal areas of the patients were calculated in cm^2 in Microsoft® Excel 2000 program (Fig. 3).

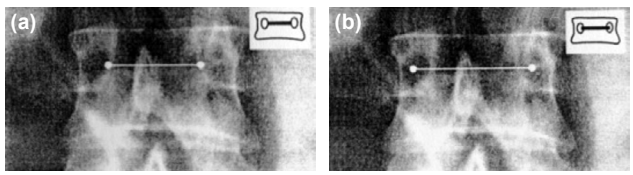

Figure 2. (a) Interpedicular distance measurements made on anteroposterior radiographs. Medial-to-medial interpedicular distance measurement, and **(b)** middle-to-middle interpedicular distance measurement.

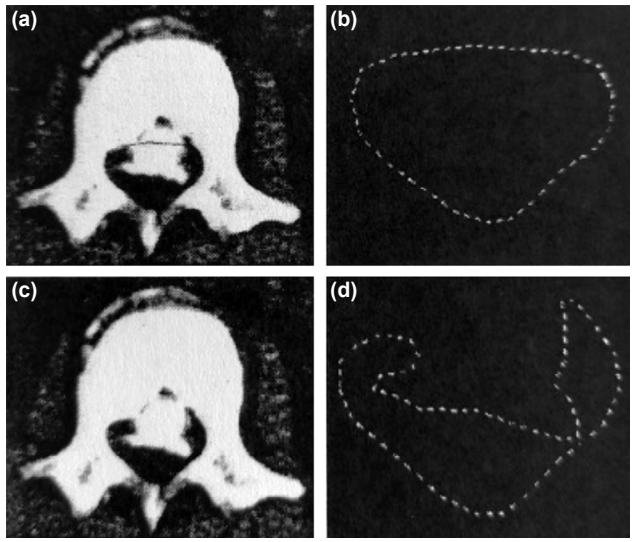

Figure 3. (a) Measurements made to determine the canal compromise ratio in computed tomography sections. Determination of normal canal area with "polyline" tool and with the help of extrapolation, **(b)** boundaries of the area drawn with the "polyline" tool for normal canal area detection, **(c)** determining the compromised canal area with the "polyline" tool, and **(d)** boundaries of the area drawn with the "polyline" tool for detecting the compromised canal area.

Statistical Methods

Correlation and linear regression analysis of the medial-to-medial interpedicular distance increase ratio, middle-to-middle interpedicular distance increase ratio, and intracanal compromise ratio of fracture levels of the patients was performed using the SPSS v.11.5 statistical program. In addition to these correlation and regression analyses, the relationship between the fracture level, fracture type and presence of neurological damage, interpedicular distance, medial-to-medial and middle-to-middle interpedicular distance increase ratios, and intracanal compromise ratio was also investigated. In these studies, the Mann–Whitney U test was used to compare two independent samples in non-parametric tests. The statistical significance level was accepted as $p<0.05$.

RESULTS

A statistically significant relationship was found when comparing the medial-to-medial and middle-to-middle interpedicular distance increase ratio ($p<0.001$), with a Pearson's correlation coefficient of 0.89, which meant a "strong" correlation (Fig. 4a).

When the medial-to-medial increase ratio and the canal compromise ratio were compared, a statistically significant relationship was detected ($p<0.001$). The Pearson's correlation coefficient of 0.60 confirmed the presence of a "moderate" correlation between the two variables (Fig. 4b).

When comparing the middle-to-middle interpedicular distance increase ratio and the canal compromise ratio, a statistically significant relationship was observed ($p<0.001$). The Pearson's correlation coefficient of 0.63 confirmed that the correlation between the two variables was "moderate" (Fig. 4c).

Higher interpedicular distance increase and canal compromise ratios were found in the transitional fractures when compared to lower levels. However, the Mann–Whitney U test showed no statistically significant difference between the two groups in terms of the interpedicular distance increase and canal compromise ratios.

In Type A burst fractures, higher interpedicular distance increase and canal compromise ratios were found when compared to Type B burst fractures. However, the Mann–Whitney U test showed no statistically significant difference between the two groups in terms of either medial-to-medial and middle-to-middle increase in interpedicular distance or canal compromise ratios.

In patients with neurological deficits, higher interpedicular distance increase and canal compromise ratios were found when compared to those without deficits. However, the Mann–Whitney U test showed no statistically significant difference between the two groups in terms of either medi-

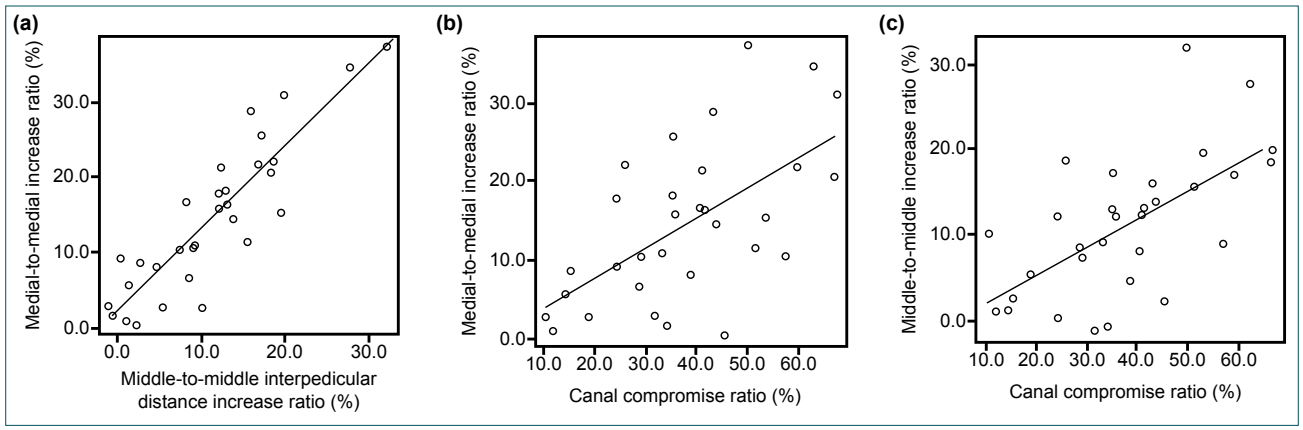

Figure 4. (a) Correlation between medial-to-medial and middle-to-middle interpedicular distance increase ratio. Linear regression line is also drawn. (medial-to-medial increase ratio = 2.31+1.10 × middle-to-middle increase ratio, R^2=0.79), **(b)** correlation between medial-to-medial interpedicular distance increase ratio and canal compromise ratio. Linear regression line is also drawn. (medial-to-medial increase ratio = 0.14+0.38 × canal compromise ratio, R^2=0.36), and **(c)** correlation between middle-to-middle interpedicular distance increase ratio and canal compromise ratio. Linear regression line is also drawn. (middle-to-middle increase ratio = 0.99+0.32 × canal compromise ratio, R^2=0.39).

al-to-medial and middle-to-middle increase in interpedicular distance or canal compromise ratios.

DISCUSSION

In burst fractures, narrowing of the spinal canal due to retropulsion of the bone fragments from the posterior of the corpus is important because of the possibility of compression of the neural elements. For this reason, many studies have been performed on different radiological parameters and morphological changes caused by burst fractures.[5–13] Meanwhile, the rate of invasion of the spinal canal with bone fragments has been the subject of various studies.[14–16] This rate has been used as a vital parameter in various studies on the diagnosis and treatment of burst fractures.[17–21] In addition to these studies, the only study investigating the relationship between the spinal canal and linear area measurements is that of Frank and Bonsell.[22] However, this study was performed only on CT sections. The same sections were used for both the AP canal diameter and area measurements, and the results were compared. In our study, the interpedicular distance, which can be easily measured on direct radiographs, was compared with the canal compromise. In other words, how close a ratio can be estimated in cross-sectional imaging based on direct radiographs that were investigated. Based on the records of 10 patients, Frank and Bonsell[22] concluded that linear measurements overestimated the rate of canal invasion. The linear AP diameter and the linear parameter examined in their statistically insignificant study cannot be considered reliable due to the difficulty in determining the boundaries and superposition of the canal in direct lateral radiographs. Therefore, CT imaging was required. In this retrospective study based on randomly selected patients, the obliquity of some sections was inevitable, which, as shown by Schönström[23] would lead to errors in the measurement of the canal area. In the planning stage of our study, this situation was taken into account. The topograms of the patients to be included in the study and hence the cross-sectional planes were examined. Then, the patients with an oblique cross-sectional plane were excluded from the study.

Schönström[23] reported that the canal area would appear to be increased in non-orthogonal sections, but showed that this increase would be <4% in angles smaller than 15°. Here, another critical problem is determining the size of the normal canal area at the fracture level before the occurrence of the fracture. The calculation of this area is based on the upper and lower normal levels, and the average of these calculations is taken;[14,17] oblique sections may be used at least at one, sometimes both, of these levels. However, taking oblique sections into calculations may result in an error that will affect the results, estimating the canal area at the fracture level larger than usual, and hence showing the canal compromise lower than normal. Preventing this problem would have been possible with a prospective study that used a predefined CT protocol, not a retrospective study like ours. Therefore, we used extrapolation to determine the canal boundaries to estimate the normal canal area value. However, using this method and thus performing the measurements at a level where the interpedicular distance increases and the canal area changes might be considered a disadvantage. This is a point of criticism for our study.

In this study, the interpedicular distance measurement was not only performed from medial-to-medial but also from middle-to-middle. Considering that the interpedicular distance provides the transverse dimensions of the spinal canal, only medial-to-medial measurements can be considered sufficient. However, in some cases where there is no rotation in the spine (the pedicle distance from the border or midline of the corpus is equal), shape asymmetries can be observed between the two sides. Sometimes, especially at the lower lumbar levels, the pedicles take a more circular shape than the upper levels, and the middle-to-middle measurement may

change even if the medial-to-medial measurement does not change when compared to the upper levels. To reduce the errors that may occur due to these medial-to-medial measurements, middle-to-middle measurements were also performed. Correlation analyses were also repeated for these measurements. As a result, we found that the interpedicular distance increase ratio based on middle-to-middle interpedicular distance measurements (although the difference was not significant) showed a higher correlation with the canal compromise ratio when compared to medial-to-medial measurements. Since our study investigated the relationship between the interpedicular distance increase ratio and canal compromise ratio, we did not need to express the computerized measurements on scanned images in real units, such as cm or cm^2. However, normalization was performed by using a scale ruler on direct radiographs and using its scales on cross-sectional images to render the comparison of interpedicular distance and canal area values with other studies possible, where we saw that our results were similar to those from the literature.[24–26] In evaluation of 60 healthy subjects based on measurements made using CT in the normal interpedicular distance values between T12 and L3 between 2 and 2.8 cm, Ulrich et al.[26] reported that the canal area values varied between 2 and 3 cm^2. The authors considered the interpedicular distance values <16 mm in the lumbar region and canal area values <1.45 cm^2 as lower than normal values. In another study, Karantanas et al.[27] reported that the mean value of interpedicular distance at the pediculo-laminary level for L3 was 2.36 cm, and the mean area of the spinal canal was 2.69 cm^2. In Tacar et al.'s[25] study, the interpedicular distance values reported from Turkey for men and women, respectively, were as follows; 26.7 cm and 25.4 cm at L1, 27.4 cm and 26.0 cm at L2, and 28.5 cm, and 27.2 cm at L3.

When performing canal area measurements on the CT and MRI films, the section with a greenstick lamina fracture,[4] which is common in burst fractures, is not included in the calculation of the canal area. Inclusion of this section in the compromised canal area would cause the canal compromise ratio that would cause neurological damage to be lower than its actual value. However, this area cannot reduce pressure. On the contrary, at lower lumbar levels, cauda equina fibers can be trapped and may cause additional problems.

According to the burst fracture levels of the patients, the percentages of interpedicular distance increase and the percentages of canal compromise were higher at the T12 and L1 levels, which are accepted as thoracolumbar transition regions, when compared to L2 and L3 levels. This finding was interpreted as the effect of more forces due to stress concentration in the transition zone and thus a more serious fracture damage. When the examination was performed according to the burst fracture types from the same angles, the higher values in Type A fractures were observed when compared to Type B fractures. Type A fractures are more damaged fractures where both endplates are fractured,[3,4] and this is manifested by an increased interpedicular distance and an increased canal compromise. When we compared the percentages of interpedicular distance increase and canal compromise according to the neurological status, we observed that patients with neurological deficits had higher values. This was also expected since the neurological deficit is higher in fractures with a more severe damage. The insufficient number of patients in the groups may explain the absence of a statistically significant difference between these parameters.

Conclusion

A moderate correlation was found between the interpedicular distance increase and canal compromise ratios in burst fractures. However, the coefficients found were not sufficient to make a reasonable estimate for the majority of the population. We believe that it is more appropriate to evaluate the canal compromise ratio using CT or MRI, which are cross-sectional imaging methods, since estimations based on radiographs may lead to incorrect treatment options.

Ethics Committee Approval: This study was approved by the İstanbul University Cerrahpaşa Faculty of Medicine Ethics Committee (Date: 06.12.2005, Decision No: 33993).

Peer-review: Internally peer-reviewed.

Authorship Contributions: Concept: B.T., Ö.A., M.C.Ü., N.B., M.H.; Design: B.T., Ö.A., M.C.Ü., N.B., M.H.; Supervision: B.T., Ö.A., M.C.Ü., N.B., M.H.; Resource: B.T., Ö.A.; Data: B.T., Ö.A.; Analysis: B.T., Ö.A., M.C.Ü., N.B., M.H.; Literature search: B.T., Ö.A., M.C.Ü.; Writing: B.T., Ö.A.; Critical revision: B.T., Ö.A., M.C.Ü., N.B., M.H.

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ORİJİNAL ÇALIŞMA - *ÖZ*

Torakolomber omurga burst kırıklarında interpediküler mesafe artış oranı ve spinal kanal işgal oranı arasındaki ilişkiler

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AMAÇ: Torakolomber burst kırıklarında anteroposterior direkt radyografilerdeki ölçümlere dayanarak hesaplanan interpediküler mesafe artış oranı ile kesitsel görüntülere dayanarak hesaplanan kanal içi işgal oranı arasındaki ilişkiyi hesaplamak.
GEREÇ VE YÖNTEM: İstanbul Üniversitesi Cerrahpaşa Tıp Fakültesi, Ortopedi ve Travmatoloji Servisi'nde torakolomber omurga burst kırığı nedeniyle tedavi olmuş, ortalama yaşları 30.8 (14–57), olan 18'i erkek, 13'ü kadın 31 hasta çalışmaya alındı. Hastaların tedavi öncesi direkt anteroposterior radyografilerinden yararlanılarak interpediküler mesafenin içten-içe ve ortadan-ortaya yapılan ölçümlerdeki artış oranları hesaplandı. Kırık seviyeden geçen bilgisayarlı tomografi ya da manyetik rezonans görüntüleme transvers kesitlerinden yararlanılarak da burst kırığına bağlı retropulse kemik fragmanı nedeniyle daralmış olan spinal kanalın işgal oranları hesaplandı. Hesaplanan bu oranlar arasındaki ilişki korelasyon ve lineer regresyon analizleri ile araştırıldı.
BULGULAR: İnterpediküler mesafenin içten-içe ve ortadan-ortaya yapılan ölçümleri arasında "çok iyi" düzeyde korelasyon (Pearson korelasyon katsayısı: 0.89, $p<0.001$) saptanırken; kanal içi işgal oranları ile interpediküler mesafe içten-içe ve ortadan-ortaya artış oranları arasında ise "iyi" düzeyde korelasyon (Pearson korelasyon katsayısı sırasıyla 0.60 ve 0.63, $p<0.001$) saptandı. Hastaların kırık seviyeleri, kırık tipleri ve nörolojik durumları ile interpediküler mesafe artış oranları ve kanal-içi işgal yüzdeleri arasında istatistiksel olarak anlamlı bir ilişki saptanmadı.
TARTIŞMA: Bu çalışmada elde edilmiş olan korelasyon katsayıları göz önünde bulundurulduğunda; sadece direkt radyografilerdeki interpediküler mesafe artış oranlarına dayanarak kanal-içi işgal oranı saptamak, birçok hastada önemli hatalara neden olabilecek bir yöntem olarak görülmektedir.
Anahtar sözcükler: İnterpediküler mesafe; spinal kanal işgali; torakolomber burst kırığı.

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